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Assessment of air pollution tolerance index (APTI) and anticipated performance index (API) of selected roadside plant species for the green belt development at Ratnagiri City in the Konkan region of Maharashtra, India

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Abstract Small towns are becoming hotspots of pollution due to industrial, urbanisation, and domestic activities. Air pollution affects human health and it is also responsible for physiological changes in plants. Green belt development programmes are cost-effective for the minimisation of air pollution. In the present study, to calculate air pollution tolerance index (APTI) and anticipated performance index (API), samples of 25 plant species were collected from each area i.e. the industrial (I), urban (U), and rural (R) areas and analysed for different parameters. Amongst all three areas, APTI of *Artocarpus heterophyllus* (46.74), *Calotropis gigantea* (43.63), and *Bauhinia racemose* (42.11) have shown the highest values and these plants can act as an inhibitor of air pollution. Also, the APTI of *Ocimum tenuiflorum* has found to be the lowest (12.05, 11.32, 12.86) as compared to other plant species amongst the three areas. Statistical analysis reveals that values of R^2 are consistent in case of total chlorophyll (TC) and ascorbic acid (AA). API index showed the efficiency of *Calotropis gigantea* (excellent), *Artocarpus heterophyllus* (very good), and *Mangifera indica* (very good) for the green belt development around the selected areas. It is recommended to plant above-mentioned plant species along the roadside by considering their air pollution tolerance ability and medicinal as well as economic importance. Furthermore, it is suggested to plant species of *Artocarpus heterophyllus* (jackfruit) and *Mangifera indica* (Alphonso mango) which will generate income source for the local government bodies (Ratnagiri Municipal Council), as the fruits and wood of these plants can be exported and sold.

Keywords Bio-indicator · Pollution tolerance ability · *Artocarpus heterophyllus* (jackfruit) · *Calotropis gigantea* (Rui)

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Introduction

In developing countries, the factors responsible for environmental degradation are rapid urbanisation, industrialisation, and increasing number of vehicles on roads (Goswami et al., 2022; Kaur & Nagpal, 2017; Malav et al., 2022). These activities are also responsible for the increase in air pollution (Patel et al., 2023; Patil et al., 2021) and loss of green cover (Pandeya et al., 2015b; Timilsinaa et al., 2021; Pandeya et al., 2016). Urban and sub-urban areas of many states have endangered green spaces due to urban sprawl (Pandeya et al., 2015a). Also, due to the increase in air pollution in cities, the existing flora is badly affected (Achakzai et al., 2017). Nowadays, urban areas are becoming a hotspot of air pollution

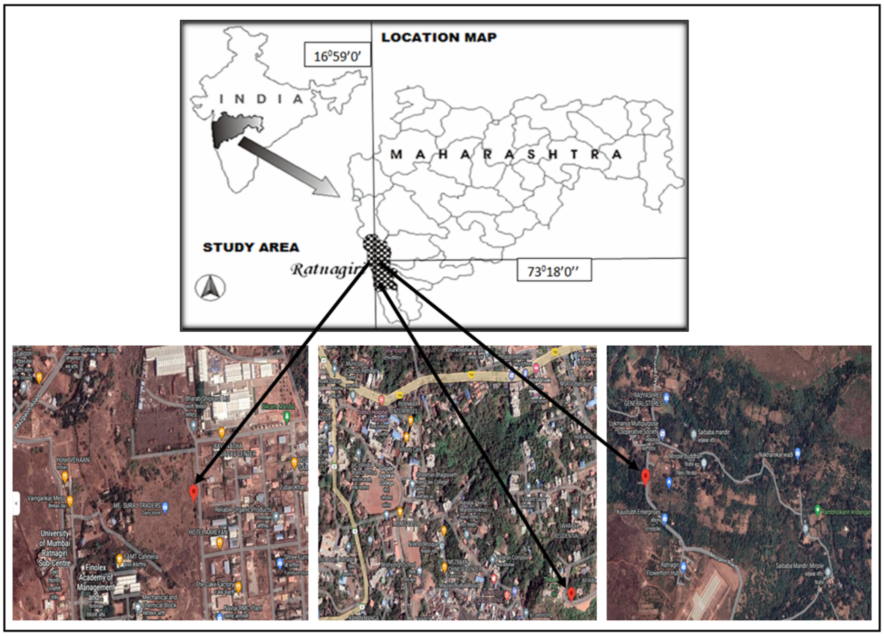
(Agbaire & Arienrhe, 2009; Dash & Dash, 2018; Patil et al., 2022). Physiological, morphological, and biological changes in plants are affected by air pollution (Anake et al., 2018; Anake et al., 2022; Bui et al., 2021; Kaur & Nagpal, 2017; Kazi & Kulkarni, 2020; Joshi & Swami, 2007; Saleem et al., 2022). Exposure to airborne pollutants conveys physiological changes to plants and it may show physical damage (Joshi et al., 2016; Molnara et al., 2020). From several studies, researchers indicated that plants are inhibitors and also act as indicators of air pollution (Zouari et al., 2018; Leghari et al., 2011; Agbaire & Arienrhe, 2009; Tak & Kakde, 2020). Plants play an important role in reducing air pollution as they absorb pollutants in the atmosphere, and also, they are good receptors to all types of air pollutants (Bhadauria et al., 2022; Govindaraju et al., 2012; Malav et al., 2022; Prajapati & Tripathi, 2008; Rai & Panda, 2014; Sahu et al., 2020). Plants can be used as bio-indicators for monitoring the local air quality (Das et al., 2010; Begum & Harikrishna, 2010; Akilan & Nandhakumar, 2016; Bala et al., 2022). Tolerant plant species may be used as a sink for air pollutants and sensitive plant species as bio-indicators (Vyankatesh & Bhosale, 2014; Panigrahi et al., 2012).

APTI and API can be considered good tools to select the best plant species for green belt development (Singh et al., 1991; Gupta et al., 2016; Hozhabralsadat et al., 2022; Pandeya et al., 2015a; Pandeya et al., 2015b; Kaur & Nagpal, 2017; Molnara et al., 2020). Also, the environmental stress on the flora is measured by APTI and the four biochemical parameters viz. pH (P), relative water content (RWC), ascorbic acid (AA), and total chlorophyll (TC) are used to calculate APTI (Nayak et al., 2015; Mandal & Dhal, 2022; Sarkar et al., 2021) and other biological and socioeconomic parameters observed to calculate API (Singare & More, 2020; Verma et al., 2023). Ascorbic acid acts as an antioxidant and imparts resistance to air pollution in plants, and higher values of pH, total chlorophyll, and relative water content in plants favour tolerance to pollutants (Ogunkunle et al., 2015; Sahu et al., 2020). The APTI and API study is beneficial for green belt development in a polluted area of cities or urbanising towns (Gharge & Menon, 2012; Ochoa et al., 2022; Tak & Kakde, 2020). Many researchers have studied APTI and API for metropolitan or mega cities (Joshi et al., 2016; Alotaibi et al., 2020; Mondal & Singh, 2022), but there is a very limited approach towards the studies for small towns or urbanising cities in Maharashtra. Ratnagiri is an urbanising city in the Konkan region which is leading towards increasing air pollution–related activities, and it will be an emerging need for green belt development towards air pollution. According to the studies, it is needful to make people aware of air pollution and to develop green belts in urbanising cities or small towns. Considering the ecological aura of the Konkan region, the present study area is more suitable for APTI study. According to several studies, APTI and API for green belt development of Ratnagiri City have not been conducted by researchers before. In the present study, the economic and air pollution tolerance values of *Calotropis gigantea* (Rui), *Artocarpus heterophyllus* (jackfruit), and *Mangifera indica* (Alphonso mango) were studied. These native plants have a significant contribution to the study. Also, this is a first attempt towards the study for green belt development and APTI as well as API of 25 roadside plant species selected at each of the three areas in Ratnagiri City. However, the present study leans towards green belt development and recommends planning environmental awareness programmes for Ratnagiri City.

Materials and methods

Description of study area

Ratnagiri district in the Konkan region of Maharashtra has a great ecological diversity. It is famous for the Alphonso mango and cashew nut production and its export. Also, this city has vast biodiversity including endemic and rare medicinal plants. The sampling points were selected around Ratnagiri City, Maharashtra (latitude: 16° 59′ N; longitude: 73° 18′ E) (Fig. 1). As per the distribution, surrounding, and pollution-related activities, three areas viz. industrial (I), urban (U), and rural (R) were selected for the study. The first is an industrial (I) area (17°00′49.0″N; 73°20′21.5″E) surrounded by several industries such as food packaging, marine products, chemical industries, and casting of aluminium as well as iron and other small-scale industries. Also, the main road passes through the sampling locations. The second one is an urban (U) area around the Hindu Colony (residential area) and the Jaystambh Chowk (16°59′05.9″N; 73°18′30.3″E). This site represents commercial and residential areas having moderately



Rural Area (R) Urban Area (U) Industrial Area (I)

Fig. 1 Map of the study area showing industrial, urban, and rural areas of Ratnagiri City, Maharashtra, India

trafficular activities. Also, the third area which is the least trafficular area outside the city limits, i.e. Mazgaon Road – Patilwadi Road, is considered a rural (R) area (17°01′28.1″N; 73°19′51.6″E).

Collection of samples

This study was performed during the summer season of 2022 (Feb–May). The study areas experienced hot summer. In the study area, the temperature varies from 11.6 to 26 °C, 14.4 to 27.4 °C, 18.9 to 32.3 °C, and 20.8 to 30 °C during the month of February, March, April, and May, respectively. For the present study, 25 plant species (roadside plants) (Table 1) were selected from industrial (I), urban (U), and rural (R) areas respectively. Also, the same species were selected from each area (roadside plants). Then, the samples were collected during the daytime and were stored in polyethene bags, quickly taken to the laboratory and preserved (4 °C) (Bhadauria et al., 2022). Then, the samples were analysed for different parameters in the laboratory of the Department of Environmental Science, Ratnagiri Sub-Campus, University of Mumbai.

Analytical methods

Collected and preserved leaf samples were brought to the laboratory for analysis. Each sample was then washed with distilled water to clear dust and other physical impurities. pH (P) of leaf extract was analysed according to the method described by Sharma et al. (2020), using a digital pH metre. The determination of relative water content (RWC) and total chlorophyll (TC) was carried out as per the proposed method and formula by Sahu et al. (2020). Ascorbic acid content (AA) was calculated considering Banerjee et al. (2021).

APTI

Calculation of the APTI was done as per the formula described by Singh and Rao (1983) as given in Eq. (1),

$$APTI = \frac{AA(TC + P) + RWC}{10} \tag{1}$$

where

Table 1 Botanical and local names of the selected plant species at I, U, and R areas

Sr. no	Plant name (botanical)	Plant name (local)	Classification of plant	Sr. no	Plant name (botanical)	Plant name (local)	Classification of plant
1	*Manilkara zapota*	Chiku	Tree	16	*Osmunda regalis*	Royal fern	Shrub
2	*Calotropis gigantea*	Rui	Shrub	17	*Azadiracta indica*	Neem	Tree
3	*Magnifera indica*	Mango	Tree	18	*Cordyline fruticosa*	Ti plant	Shrub
4	*Hibiscus rosa-sinensis*	Jaswand	Shrub	19	*Thevetia peruviana*	Yellow oleander	Tree
5	*Carica papaya*	Papaya	Tree	20	*Cymbopogon citrates*	Gavati chaha	Grass
6	*Carissacarandas*	Karvand	Shrub	21	*Cocos nucifera*	Coconut	Tree
7	*Acacia auriculiformis*	Akashia	Tree	22	*Saraca asoca*	Asoka	Tree
8	*Anacardium occidentale*	Kaju	Tree	23	*Bauhinia racemosa*	Apta	Tree
9	*Psidium gaujava*	Peru	Tree	24	*Artocarpus heterophyllus*	Jackfruit	Tree
10	*Tectona grandis*	Sag	Tree	25	*Catharanthus*	Sadafuli	Herb
11	*Ocimum bassillicum*	Holy basil oil	Herb				
12	*Plumaria rubra*	Firangipani	Tree				
13	*Eagle marmelos*	Bael	Tree				
14	*Abus precatorius*	Rosary pea	Shrub				
15	*Ocimum tenuiflorum*	Tulsi	Herb				

AA = ascorbic acid content of leaf mg/g dry weight
TC = total chlorophyll content of leaf mg/g dry weight
P = leaf extract pH
RWC = percent relative water content of the leaf. The total sum is divided by 10 to get a manageable value

API

The air pollution tolerance index (APTI) of selected plant species was calculated for three areas such as industrial, urban, and rural areas. The anticipated performance index (API) was computed by using final APTI values and characters such as biological and socioeconomic. For the particular tolerant plant species for green belt development, grades (+, −) have been allocated to the plant species according to the final values. API, percentage score, and grade allocation were done according to several studies (Enitan et al., 2022; Malav et al., 2022; Rai & Panda, 2014; Govindaraju et al., 2012).

$$\%Score = \frac{No\ of\ (+)\ obtained\ by\ any\ plant\ species}{Maximum\ No\ of\ (+)\ for\ any\ plant\ species} \times 100 \tag{2}$$

Statistical analysis

Standard deviation and basic statistical applications were performed by using MS Excel 2007. Correlation and regression were calculated in VassarStats (http://vassarstats.net/). Graphical presentations were done by using Origin software.

Results and discussion

pH of leaf extract (P)

In the physiological process of plants, pH has an important role as it determines the rate of photosynthesis of plants (Zouari et al., 2018). In the present study, pH values ranged from 3.7 to 7.85 in the I area, 3.23–6.72 in the U area, and 3.96–7.92 in the R area (Table 2). Amongst all three areas, most of the plants have shown acidic pH. At the R area, *Hibiscus rosa-sinensis* has the highest pH (7.92) as compared to the I and U areas. Also, *Tectona grandis* has the lowest pH (3.7) at the I area.

Table 2 Biochemical parameters of plant species at I, U, and R areas

Sr. no	Plant name	Industrial (I)				Urban (U)				Rural (R)			
		P	TC (mg/g)	RWC %	AA (mg/100 ml)	P	TC (mg/g)	RWC %	AA (mg/100 ml)	P	TC (mg/g)	RWC %	AA (mg/100 ml)
1	*Manilkara zapota*	6.92	16.38	61.36	4.8	6.55	16.12	61.08	4.79	6.95	16.7	61.33	4.9
2	*Calotropis gigantea*	6.7	57.42	62.82	5.71	6.51	58.27	62.93	5.61	6.9	57.49	62.82	5.8
3	*Magnifera indica*	6.42	36.09	52.02	4.89	6.32	36.03	51.89	4.76	6.65	36.45	52.97	4.9
4	*Hibiscus rosa-sinensis*	7.85	55.09	50.97	4.96	6.01	54.69	50.63	5.05	7.92	55.61	51.54	5.07
5	*Carica papaya*	6.11	32.78	35.21	6.44	6.72	32.6	35.07	5.98	6.35	33.08	35.61	6.51
6	*Carissaca-randas*	6.53	36.86	48.1	4.1	6.13	36.04	47.96	3.94	6.75	37.02	48.36	4.22
7	*Acacia auriculi-formis*	5.07	42.24	59.26	5.24	6.07	41.63	59.35	5.11	5.36	42.65	60.75	5.21
8	*Anacardium occiden-tale*	4.75	42.32	51.04	3.41	4.65	41.54	50.65	3.26	4.83	42.73	52.58	3.55
9	*Psidium gaujava*	6.35	35.19	61.25	3.89	6.03	34.91	60.69	3.59	6.86	35.56	61.53	3.86
10	*Tectona grandis*	3.7	31.12	35.42	5.69	3.23	30.9	34.96	5.49	3.96	31.28	35.73	5.76
11	*Ocimum bassilli-cum*	6.4	32.51	42.89	3.79	5.89	31.06	49.82	3.69	6.11	32.8	51.03	4.01
12	*Plumaria rubra*	6.7	32.14	50.51	6.91	6.01	31.25	50.1	6.79	6.8	32.99	51.83	7.05
13	*Eagle marmelos*	5.3	36.76	43.24	6.56	5.85	36.91	24.97	6.76	5.43	36.93	43.8	6.96
14	*Abus preca-torius*	6.7	33.57	25.11	5.6	5.82	32.85	24.57	5.7	6.83	33.63	25.56	5.8

Table 2 (continued)

Sr. no	Plant name	Industrial (I)				Urban (U)				Rural (R)			
		P	TC (mg/g)	RWC %	AA (mg/100 ml)	P	TC (mg/g)	RWC %	AA (mg/100 ml)	P	TC (mg/g)	RWC %	AA (mg/100 ml)
15	*Ocimum tenuiflorum*	5.51	22.2	26.24	3.4	5.07	21.82	26.11	3.24	6.05	22.8	26.46	3.54
16	*Osmunda regalis*	5.7	22.3	36.86	8.5	5.2	21.85	35.81	8.75	6.02	22.39	37.07	8.51
17	*Azadiracta indica*	6.7	34.05	53.86	4.3	6.46	33.89	53.07	4.01	6.8	34.54	44.01	4.7
18	*Cordyline fruticosa*	6.3	26.93	43.15	6.1	5.82	25.8	42.88	6	6.01	27.01	60.11	6.05
19	*Thevetia peruviana*	6.4	20.6	59.84	4.2	5.54	19.75	58.88	4.15	6.67	20.66	59.97	4.2
20	*Cymbopogon citrates*	5.6	24.61	55.5	8.1	5.91	23.88	54.82	7.95	6.02	24.71	55.64	7.97
21	*Cocos nucifera*	6.4	26.94	68.76	4.24	4.87	25.65	67.82	4.11	6.81	27.02	68.83	4.49
22	*Saraca asoca*	5.9	25.66	51.8	4.7	6.01	24.84	50.96	4.6	6.01	26.04	52.04	4.9
23	*Bauhinia racemosa*	4.25	51.01	70.34	6.25	4.1	50.34	71.11	6.11	4.3	52.01	72.01	6.2
24	*Artocarpus heterophyllus*	5.8	52.02	32.12	7.41	5.4	51.75	32	7.35	6.07	52.58	32.81	7.41
25	*Catharanthus*	5.55	35.31	53.74	6.2	4.9	35.25	52.89	6.1	5.9	35.61	54.04	6.3
Minimum		**3.7**	**16.38**	**25.11**	**3.40**	**3.23**	**16.12**	**24.57**	**3.24**	**3.96**	**16.7**	**25.56**	**3.54**
Maximum		**7.85**	**57.42**	**70.34**	**8.50**	**6.72**	**58.27**	**71.11**	**8.75**	**7.92**	**57.49**	**72.01**	**8.51**

P pH, *TC* total chlorophyll, *RWC* relative water content, *AA* ascorbic acid

Total chlorophyll (TC)

The productivity of plants is indexed by chlorophyll and its highest content is favourable for plants to tolerate pollutants (Yannawar & Bhosale, 2014). The TC content varied from 16.38 to 57.42 mg/g, 16.12–58.27 mg/g, and 16.70–57.49 mg/g in the I, U, and R areas respectively (Table 2). Maximum TC showed by *Calotropis gigantea* at all the areas was 57.42 mg/g at I, 58.27 mg/g at U, and 57.49 mg/g at R and minimum was 16.38 mg/g at I, 16.12 mg/g at U, and 16.7 mg/g at R areas.

Relative water content (RWC)

RWC improvises plants' ability to withstand drought stress, and the physiological balance of plants under the stress conditions is maintained (Malav et al., 2022). In the I, U, and R areas, RWC has ranged from 25.11 to 70.34%, 24.57–71.11%, and 25.56–72.01% respectively (Table 2). Along the three areas, *Bauhinia racemose* had shown higher RWC (Table 2).

Ascorbic acid (AA)

AA acts as an antioxidant and influences plants' resistance to air pollution (Alotaibi et al., 2020). Along the three areas, *Osmunda regalis* plant has shown the maximum values viz. 8.50 mg/100 ml at I, 8.75 mg/100 ml at U, and 8.51 mg/100 ml at R area (Table 2). Minimum values of *Ocimum tenuiflorum* at I, U, and R (3.40, 3.24, 3.54 mg/100 ml) areas respectively. Although AA varies depending on various environmental factors (Saleem et al., 2022), the study areas acquainted similarities in the

Table 3 APTI of plants at three areas (I, U, and R)

Sr. no	Plant name (botanical)	APTI			M	SD
		I	U	R		
1	*Manilkara zapota*	17.32	16.97	17.72	17.34	0.38
2	*Calotropis gigantea*	42.89	42.63	43.63	43.05	0.52
3	*Magnifera indica*	25.99	25.35	26.42	25.92	0.54
4	*Hibiscus rosa-sinensis*	36.32	35.72	37.36	36.47	0.83
5	*Carica papaya*	28.57	27.02	29.23	28.27	1.13
6	*Carissacarandas*	22.60	21.41	23.31	22.44	0.96
7	*Acacia auriculiformis*	30.72	30.31	31.09	30.70	0.39
8	*Anacardium occidentale*	21.15	20.12	22.14	21.14	1.01
9	*Psidium gaujava*	22.28	20.77	22.53	21.86	0.95
10	*Tectona grandis*	23.35	22.23	23.87	23.15	0.84
11	*Ocimum bassillicum*	19.04	18.62	20.71	19.45	1.11
12	*Plumaria rubra*	31.89	30.31	33.23	31.81	1.46
13	*Eagle marmelos*	31.92	31.40	33.86	32.39	1.30
14	*Abus precatorius*	25.06	24.50	26.02	25.19	0.77
15	*Ocimum tenuiflorum*	12.05	11.32	12.86	12.08	0.77
16	*Osmunda regalis*	27.49	27.25	27.88	27.54	0.32
17	*Azadiracta indica*	22.91	21.49	23.83	22.74	1.18
18	*Cordyline fruticosa*	24.59	23.26	25.99	24.61	1.36
19	*Thevetia peruviana*	17.32	16.38	17.48	17.06	0.59
20	*Cymbopogon citrates*	30.02	29.17	30.06	29.75	0.50
21	*Cocos nucifera*	21.01	19.33	22.07	20.80	1.39
22	*Saraca asoca*	20.01	19.29	20.91	20.07	0.81
23	*Bauhinia racemosa*	41.57	40.37	42.11	41.35	0.89
24	*Artocarpus heterophyllus*	46.06	45.21	46.74	46.00	0.77
25	*Catharanthus*	30.71	29.78	31.56	30.68	0.89
	Minimum	**12.05**	**11.32**	**12.86**	–	–
	Maximum	**46.06**	**45.21**	**46.74**	–	–

I industrial, *U* urban, *R* residential, *M* mean, *SD* standard deviation

Table 4 Grade allocation of plant species from APTI and biological, socioeconomic characters

Grading	Characters	Pattern of assessment	Grade allocated
Tolerance	APTI	0.5–9.5	+
		9.5–19.5	++
		19.5–29.5	+++
		29.5–39.5	++++
		39.5–49.5	+++++
Biological & socioeconomic	Plant habit	Small	–
		Medium	+
		Large	++
	Canopy structure	Sparse/irregular/globular	–
		Spreading crown/open/semi-dense	+
		Spreading dense	++
	Type of plant	Deciduous	–
		Evergreen	+
Laminar structure	Size	Small	–
		Medium	+
		Large	++
	Texture	Smooth	–
		Coriaceous	+
	Hardiness	Delineate	–
		Hardy	+
	Economic value	Less than three uses	–
		Three or four uses	+
		Five or more uses	++

(Source: Enitan et al., 2022)

results. This may be effected by the influence of coastal atmosphere, wind, lateritic plateaus, and lower emission sources, according to previous studies (Gude & Mhatre, 2021; Watve, 2013; Lekhak & Yadav, 2012; Gadgil et al., 2011; GOI, 1978).

Assessment of APTI and API

APTI is an index generalised to identify the plant species which tolerate air pollution the most (Singare & More, 2020). The APTI of plants in all three areas is shown in Table 3. APTI observations showed that *Artocarpus heterophyllus* has the maximum APTI along three areas viz. 46.06, 45.2, and 46.74 at I, U, and R areas respectively. *Ocimum tenuiflorum*, although having a lot of medicinal values (Bhat et al., 2015), has minimum APTI viz. 12.05, 11.32, and 12.86 at I, U, and R areas respectively. *Artocarpus heterophyllus* had shown higher APTI in all three areas followed by *Calotropis gigantea* and *Bauhinia racemose* (Table 3). *Artocarpus heterophyllus*, commonly named jackfruit, is a native plant of the Konkan region (GOM, 2016) having ease of availability. However, the results of APTI resemble the similarity between the three areas. Identical vehicular influences were found in these areas, which are important precursors for roadside plants. The studies performed on air pollution in Ratnagiri City clarified that the coastal area and lesser emission sources are the main precursors for lower air pollution (Patil et al., 2021, 2022). Also, a study by Kadam et al. (2015) concluded that the tolerance of plants to air pollution reflected according to the site specification.

Table 5 API index of plant species

Grading	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31–40	Very poor
2	41–50	Poor
3	51–60	Moderate
4	61–70	Good
5	71–80	Very good
6	81–90	Excellent
7	91–100	Best

(Source: Enitan et al., 2022)

Grade allocation and API index are shown in Tables 4 and 5 respectively. API score, allotted grades, and categorised index of plants at I, U, and R areas are shown in Tables 6, 7 and 8 respectively. Maximum API grades have been shown in *Artocarpus heterophyllus* (5) and *Calotropis gigantea* (5) at the I area (Table 6), *Mangifera indica* (4), *Calotropis gigantea* (4), and *Artocarpus heterophyllus* (5) at the U area (Table 7), and the highest amongst all plants have shown in *Calotropis gigantea* (6) at the R area (Table 8). Considering the grades allotted, the API index indicates the utility of the plant species for the green belt development (Timilsinaa et al., 2021). API index showed the suitability of *Artocarpus heterophyllus*, *Calotropis gigantea*, and *Mangifera indica* for green belt development (Tables 6, 7, and 8). In the industrial area, *Artocarpus heterophyllus* and *Calotropis gigantea* were under the very good category (Tables 5 and 6), in the urban area, *Artocarpus heterophyllus* (Tables 5 and 7) was under the very good category, and in the rural area, *Calotropis gigantea* (Tables 5 and 8) was under excellent category. *Mangifera indica* has been categorised as good at the I as well as the U area and very good at the R area. All three plants are common as well as native plants of the Konkan region, which are beneficial for the green belt development in the city. Only in the U area, *Thevetia peruviana* and *Catharanthus*

Table 6 Grades allotted to the plant species at I area

Sr. no	Plant name	Grading								Grade allotted		API value	API index
		APTI	Biological & socioeconomic			Laminar structure							
			H	C	T	S	T	H	EI	TP	%		
1	*Manilkara zapota*	++	++	–	+	+	–	+	–	7	44	2	Poor
2	*Calotropis gigantea*	+++++	++	+	–	++	–	+	+	12	75	5	Very good
3	*Magnifera indica*	+++	++	++	+	+	–	+	+	11	69	4	Good
4	*Hibiscus rosa-sinensis*	++++	+	+	+	+	+	+	–	10	63	4	Good
5	*Carica papaya*	+++	+	+	–	+	+	–	–	7	44	2	Poor
6	*Carissacarandas*	+++	–	+	–	+	–	+	+	7	44	2	Poor
7	*Acacia auriculiformis*	++++	–	–	–	–	–	+	+	6	38	1	Very poor
8	*Anacardium occidentale*	+++	++	+	–	+	+	+	+	10	63	4	Good
9	*Psidium gaujava*	+++	+	+	–	+	+	+	–	9	56	3	Moderate
10	*Tectona grandis*	+++	+	–	–	++	+	+	+	9	56	3	Moderate
11	*Ocimum bassillicum*	++	+	+	+	–	–	+	+	7	44	2	Poor
12	*Plumaria rubra*	++++	++	+	–	–	+	+	+	10	63	4	Good
13	*Eagle marmelos*	++++	–	–	–	–	+	+	–	6	38	1	Very poor
14	*Abus precatorius*	+++	–	–	+	–	–	+	–	5	31	1	Very poor
15	*Ocimum tenuiflorum*	++	–	+	+	–	–	+	+	6	38	1	Very poor
16	*Osmunda regalis*	+++	–	++	–	–	–	+	–	6	38	1	Very poor
17	*Azadiracta indica*	+++	+	+	–	+	+	+	+	9	56	3	Moderate
18	*Cordyline fruticosa*	+++	–	++	+	+	–	+	–	8	50	2	Poor
19	*Thevetia peruviana*	+++	–	++	–	–	–	+	+	6	38	1	Very poor
20	*Cymbopogon citrates*	++++	–	+	+	–	–	+	+	8	50	2	Poor
21	*Cocos nucifera*	+++	+	+	+	++	–	+	+	10	63	4	Good
22	*Saraca asoca*	+++	++	–	+	+	+	+	++	11	69	4	Good
23	*Bauhinia racemosa*	+++++	–	++	–	+	+	+	+	11	69	4	Good
24	*Artocarpus heterophyllus*	+++++	++	+	–	+	+	+	+	12	75	5	Very good
25	*Catharanthus*	++++	–	++	–	–	–	–	–	6	38	1	Very poor

APTI air pollution tolerance index, *H* habit, *CS* canopy structure, *T* type of plant, *S* size, *T* texture, *H* hardiness, *EI* economic importance, *TP* total plus

Table 7 Grades allotted to the plant species at U area

Sr. no	Plant name	Grading								Grade allotted		API value	API index
		APTI	Biological & socioeconomic			Laminar structure							
			H	C	T	S	T	H	EI	TP	%		
1	*Manilkara zapota*	++	+	+	+	–	–	+	–	6	38	1	Poor
2	*Calotropis gigantea*	+++++	+	+	–	–	+	+	+	10	63	4	Good
3	*Magnifera indica*	+++	+	+	+	+	+	+	+	10	63	4	Good
4	*Hibiscus rosa-sinensis*	++++	+	+	+	–	+	+	–	9	56	3	Moderate
5	*Carica papaya*	+++	–	+	–	+	+	+	–	7	44	2	Poor
6	*Carissacarandas*	+++	–	+	–	–	–	–	+	5	31	1	Very poor
7	*Acacia auriculiformis*	++++	++	++	–	+	–	+	+	11	69	4	Good
8	*Anacardium occidentale*	+++	+	+	–	+	+	+	+	9	56	3	Moderate
9	*Psidium gaujava*	+++	+	+	–	+	+	+	–	8	50	2	Poor
10	*Tectona grandis*	+++	–	–	–	+	+	+	+	7	44	2	Poor
11	*Ocimum bassillicum*	++	++	+	+	–	–	+	+	8	50	2	Poor
12	*Plumaria rubra*	++++	–	+	–	–	+	+	+	8	50	2	Poor
13	*Eagle marmelos*	++++	–	–	–	–	+	+	–	6	38	1	Very poor
14	*Abus precatorius*	+++	–	–	+	–	–	+	–	5	31	1	Very poor
15	*Ocimum tenuiflorum*	++	–	+	+	–	–	+	+	6	38	1	Very poor
16	*Osmunda regalis*	+++	+	++	–	–	–	+	–	7	44	2	Poor
17	*Azadiracta indica*	+++	–	+	–	+	+	+	–	7	44	2	Poor
18	*Cordyline fruticosa*	+++	–	++	+	+	–	+	+	9	56	3	Moderate
19	*Thevetia peruviana*	++	–	+	–	–	–	+	–	4	25	0	Not recommended
20	*Cymbopogon citrates*	+++	+	+	+	–	–	+	+	8	50	2	Poor
21	*Cocos nucifera*	++	+	–	+	+	–	+	–	6	38	1	Poor
22	*Saraca asoca*	++	++	–	+	+	+	+	+	9	56	3	Moderate
23	*Bauhinia racemosa*	+++++	–	+	–	+	+	+	+	10	63	4	Good
24	*Artocarpus heterophyllus*	+++++	++	–	–	++	+	+	+	12	75	5	Very good
25	*Catharanthus*	++++	–	+	–	–	–	–	–	4	25	0	Not recommended

were under the not recommended (0) category which relates to the non-feasibility for the green belt development (Tables 5 and 7). Several researchers have observed variations in APTI according to the site nature and pollution activities around the selected sites. When exposed to pollution, plant species have shown better tolerance ability at polluted sites than at the control sites (Agbaire, 2009; Gharge & Menon, 2012; Sahu et al., 2020). In this study, we found the excellent API category only in the rural area. However, in industrial and urban areas, most of the plant species were under the very poor category. Table 9 shows the studies carried out by researchers in India about APTI and API of *Calotropis gigantea*, *Artocarpus heterophyllus*, and *Mangifera indica*. From the studies, it was observed that *Calotropis gigantea* has been the least studied and, also, found non-feasibility for green belt development. But in the present study, *Calotropis gigantea* at the I, U, and R areas have shown the second highest APTI and was found excellent for the green belt development according to the API index.

Calotropis gigantea commonly named *Rui* has several medicinal aspects according to referred studies (Kumari & Sood, 2020; Seyed & Siddiqua, 2020). Having medicinal importance as well as excellent API, this plant is especially recommended for green belt development. Also, it was observed that *Artocarpus heterophyllus* and *Mangifera indica* have the feasibility for green belt development. It is well known that the fruits *Mangifera indica* (Alphonso mango) especially from the Konkan region are internationally exported. Also, *Artocarpus heterophyllus* (jackfruit) is one of the favourite fruits in the Konkan region. Several products like pulps, jams, and fries are made from this fruit. Both these plants have great economic importance. The plantation of these plants along the roadside will generate income for the local government bodies (Ratnagiri Municipal Council). *Mangifera indica* and *Artocarpus heterophyllus* plants will be the most suitable to develop a well-planned city area which acquires the air pollution tolerant ability and source of income generation.

Statistical analysis

Significant effects have been seen for correlation and regression analysis of pH (R^2=0.95 and R^2=0.94), TC (R^2=0.99 and R^2=0.99), RWC (R^2=0.89 and R^2=0.88), and AA (R^2=0.99 and R^2=0.99) on APTI. The consistency between three areas in terms of R^2 was found in the case of TC and AA (Fig. 2). APTI distribution in Fig. 3a, b and c shows similar variations of the values in the I, U, and R areas. Here, the distribution is equalised between the three areas. Figure 4a, b, c and d configure the distribution of pH, TC, RWC, and AA accordingly between the three areas. It also indicates the equalised distribution of selected plant species between the three areas. Figures 5, 6 and 7 show APTI and API distribution amongst the I, U, and R areas respectively. Figure 8 shows the total number of plants under the API category in three areas. In the R area, a total of 9 plants are under the good category and only one is under the excellent category. Also, 7 plants were under the very

Table 8 Grades allotted to the plant species at R area

Sr. no	Plant name	Grading								Grade allotted		API value	API index
		APTI	Biological & socioeconomic			Laminar structure							
			H	C	T	S	T	H	EI	TP	%		
1	*Manilkara zapota*	++	++	+	+	–	–	+	–	7	44	2	Poor
2	*Calotropis gigantea*	+++++	++	++	–	–	+	++	+	13	81	6	Excellent
3	*Magnifera indica*	+++	++	++	+	+	+	+	+	12	75	5	Very good
4	*Hibiscus rosa-sinensis*	++++	+	++	+	–	+	+	–	10	63	4	Good
5	*Carica papaya*	+++	–	+	–	+	+	–	–	6	38	1	Very poor
6	*Carissacarandas*	+++	++	+	–	–	–	+	+	8	50	2	Poor
7	*Acacia auriculiformis*	++++	++		–	+	–	+	+	10	63	4	Good
8	*Anacardium occidentale*	+++	++	+	–	+	+	+	+	10	63	4	Good
9	*Psidium gaujava*	+++	+	+	–	+	+	+	–	8	50	2	Poor
10	*Tectona grandis*	+++	++	–	–	+	+	+	+	8	50	2	Poor
11	*Ocimum bassillicum*	+++	+	+	+	–	–	+	+	8	50	2	Poor
12	*Plumaria rubra*	++++	++	+	–	–	+	+	+	10	63	4	Good
13	*Eagle marmelos*	++++	+	–	–	++	+	+	–	9	56	3	Moderate
14	*Abus precatorius*	++	+	–	+	–	–	+	–	6	38	1	Very poor
15	*Ocimum tenuiflorum*	++	–	+	+	–	–	+	+	6	38	1	Very poor
16	*Osmunda regalis*	+++	+	++	+	–	–	+	–	8	50	2	Poor
17	*Azadiracta indica*	+++	++	+	–	++	+	+	–	10	63	4	Good
18	*Cordyline fruticosa*	+++	+	++	+	+	–	+	+	10	63	4	Good
19	*Thevetia peruviana*	++	–	++	–	+	–	+	–	6	38	1	Very poor
20	*Cymbopogon citrates*	++++	+	+	+	–	–	+	+	9	56	3	Moderate
21	*Cocos nucifera*	+++	++	–	+	+	–	+	–	8	50	2	Poor
22	*Saraca asoca*	+++	++	–	+	++	+	+	+	11	69	4	Good
23	*Bauhinia racemosa*	+++++	–	+	–	++	+	+	+	11	69	4	Good
24	*Artocarpus heterophyllus*	+++++	+	–	–	++	–	+	+	10	63	4	Good
25	*Catharanthus*	++++	+	+	–	–	+	–	–	7	44	2	Poor

Table 9 Reports of other studies in India for APTI and API of selected plant species

Plant name	Location	Study site	APTI value	API category	No. of sampled plants	References
Magnifera indica	Residential & commercial	Aizwal, Mizoram	18.47	Best	12	Rai and Panda (2014)
Artocarpus heterophyllus	Thermal power plant	Neyveli, Tamil Nadu	9.90	Good	30	Govindaraju et al. (2012)
Calotropis gigantea	Heavy pollutant	Trivandrum, Kerala	8.87	Poor	67	Watson and Bai (2021)
	Rural	Ratnagiri, Maharashtra	43.63	Excellent	25	Present study
	Industrial	Ratnagiri, Maharashtra	42.89	Very good	25	
	Urban	Ratnagiri, Maharashtra	42.63	Good	25	

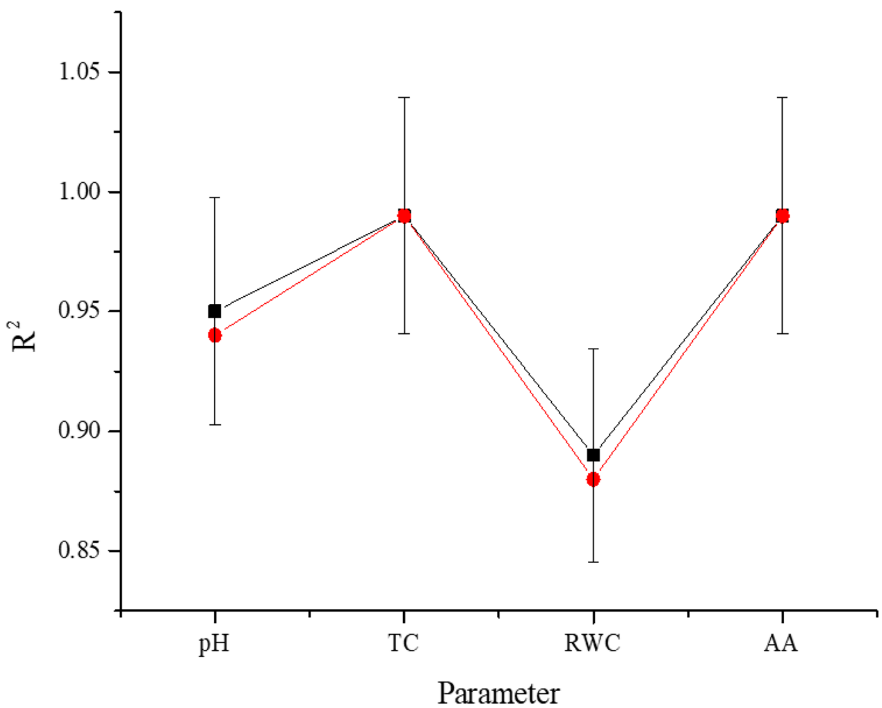
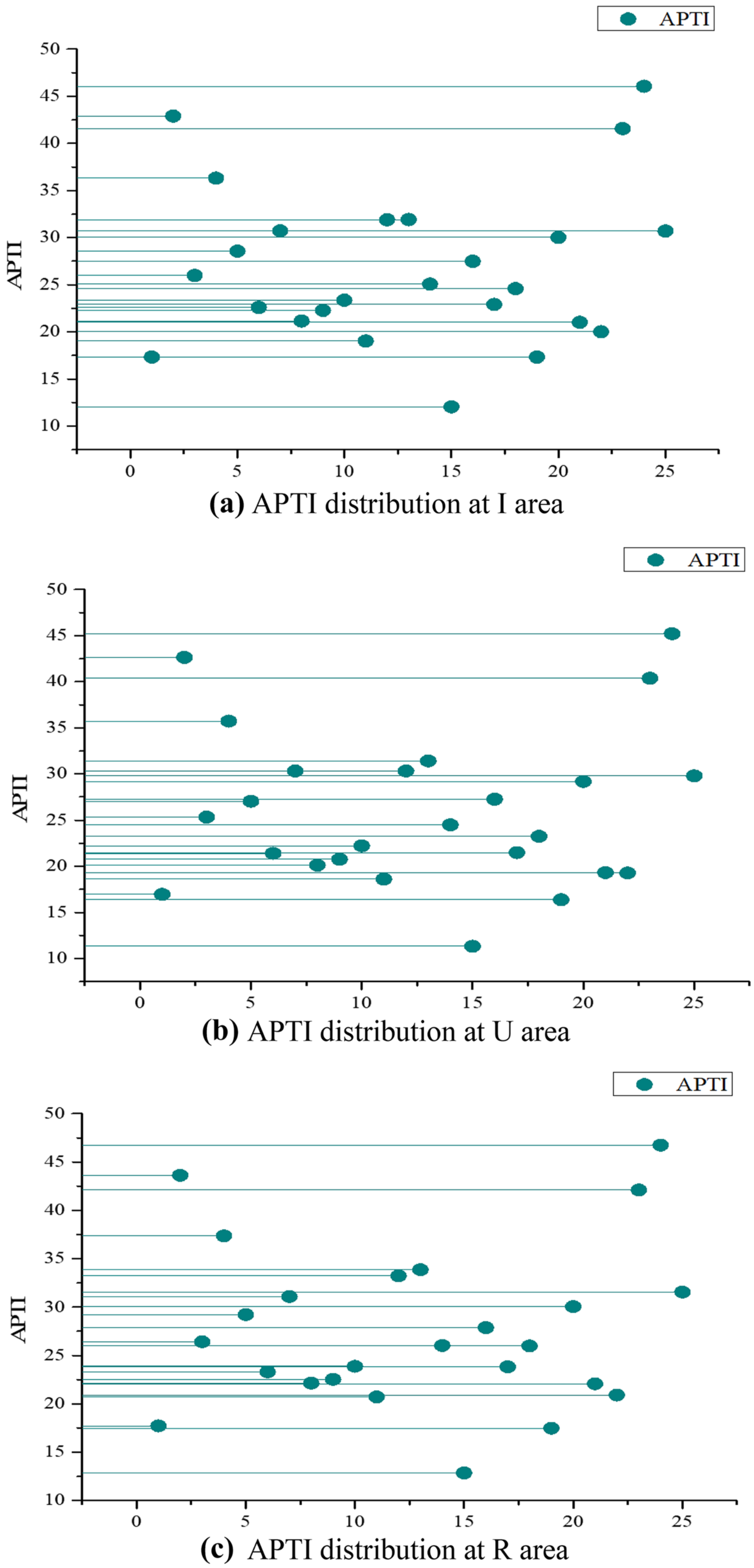


Fig. 2 Linear regression of pH, TC, RWC, and AA on APTI between three areas

Fig. 3 **a** APTI distribution at I area. **b** APTI distribution at U area. **c** APTI distribution at R area



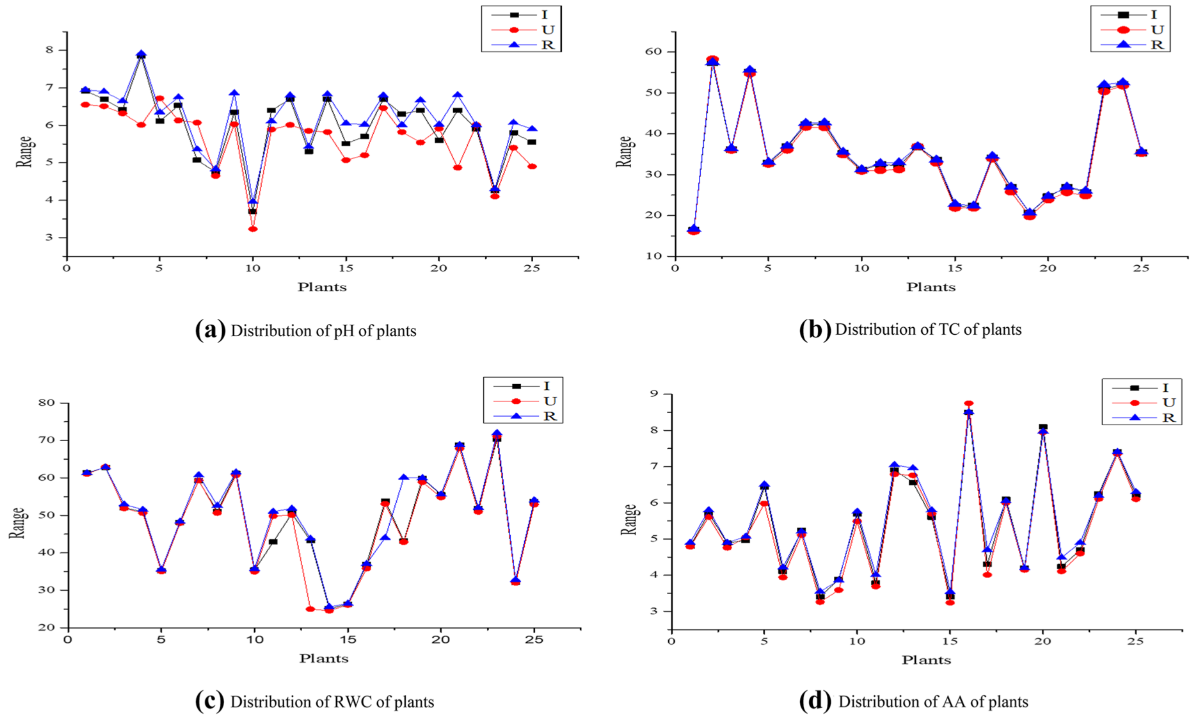


Fig. 4 **a** Distribution of pH of plants. **b** Distribution of TC of plants. **c** Distribution of RWC of plants. **d** Distribution of AA of plants

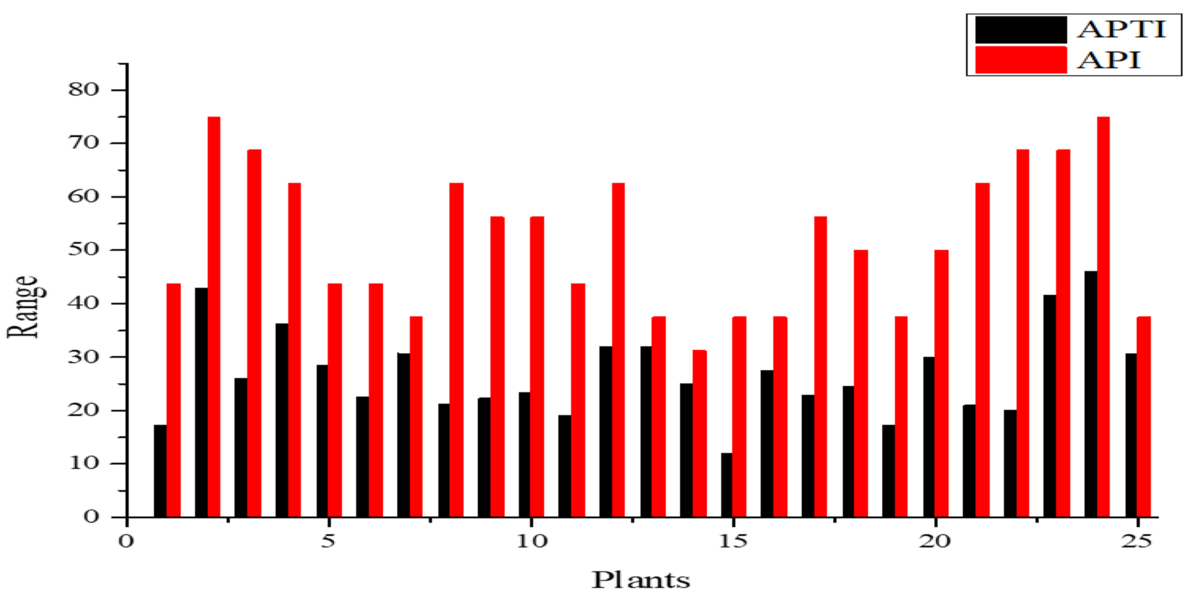


Fig. 5 APTI and API at I area

Fig. 6 APTI and API at U area

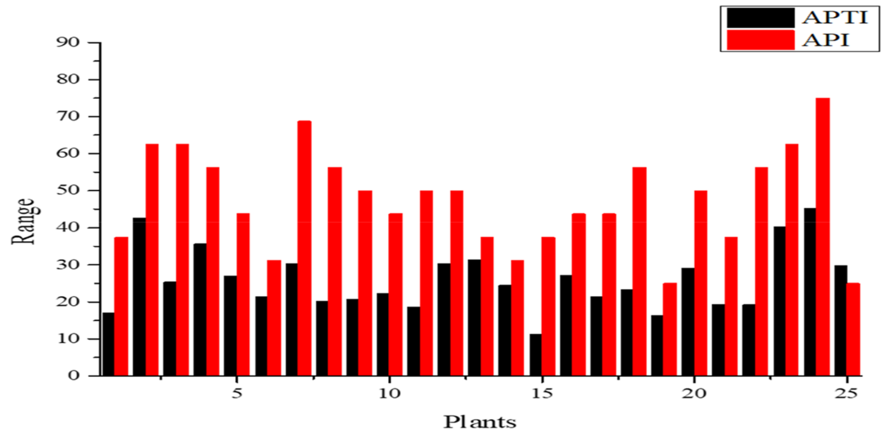
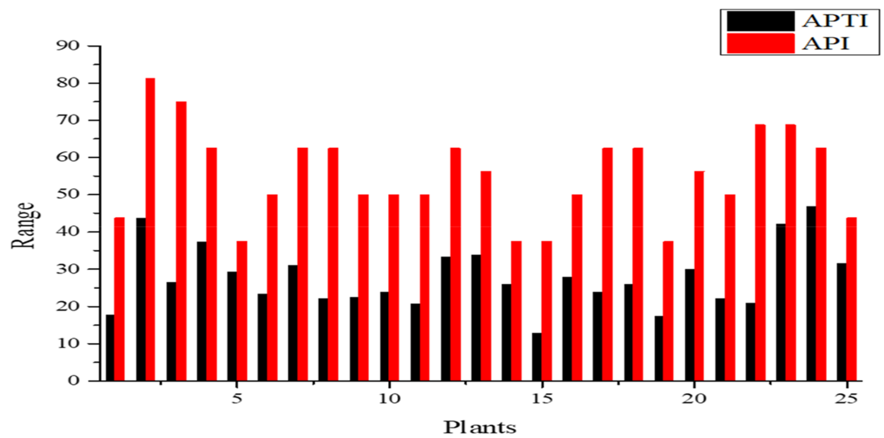


Fig. 7 APTI and API at R area



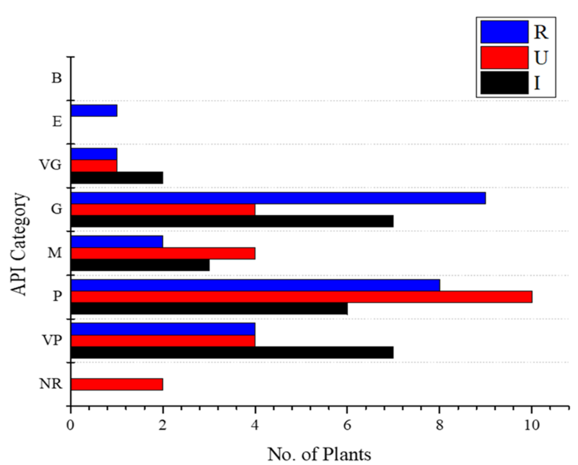


Fig. 8 No. of plants under API Categories at I, U, and R areas. NR not recommended, VP very poor, P poor, M moderate, G good, VG very good, E excellent, B best

poor category at the I and 10 plants under the poor category at the U areas respectively. This indicates that the site nature and surroundings are the important precursors for plant formability.

Conclusions

This research concludes the simplified study of APTI and API of common and native plant species at Ratnagiri City in the Konkan region of Maharashtra. The present study derivates the approach towards green belt development in consideration of the native plants in this region. The statistical analysis showed the consistency between three areas, in the case of TC and AA. According to the API index, the industrial area has the most number of very poor categories of plants and excellent categories were found only in the rural area. Whereas, in the urban area, *Thevetia peruviana* and *Catharanthus* showed non-feasibility for green belt development. It relates that the surrounding atmosphere and concerned areas are precursors to pollution tolerance values. The study further concluded that the APTI and API values differ according to the nature of the site and surrounding pollution-related activities. This is the first attempt to assess the APTI constituting with API for Ratnagiri City, which will lead to better green belt development. *Calotropis gigantea* in rural areas was under the excellent category, which can be used as an inhibitor around the industrial and urban areas. This plant is especially recommended for the green belt as this plant exhibits medicinal aspects, excellent API, and air pollution tolerance ability. While *Ocimum tenuiflorum* which has a great medicinal value showed the lowest APTI and was also categorised as very poor according to the API. *Mangifera indica* and *Artocarpus heterophyllus* have air pollution tolerance ability and these plants also come under the very good API category. These are readily available native plants of the Konkan region. Both these plants are recommended to plant around the well-planned city area as they have air pollution tolerance ability and great economic importance. Also, to create awareness amongst the people, there is a need to conduct environmental awareness programmes in Ratnagiri City.

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Data availability My manuscript and associated personal data will be shared with Research Square for the delivery of the author dashboard.

Declarations

Ethical approval All authors have read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors and are aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.

Consent to participate The authors consent to participate.

Consent for publication The author's consent for publication.

Conflict of interest The authors declare no competing interests.

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